Challenges in Sub-seasonal Prediction

Frédéric Vitart

Introduction

10 years ago, few operational centres produced sub-seasonal forecasts. Now most operational centres have forecasting systems targeting this time range.

Increased interest in sub-seasonal prediction by operational centres triggered by:

- Growing demand from applications (e.g. agriculture, health, hydrology,..)
- Progress in medium-range forecasting (1 day of predictive skill per decade). Weeks 3 and 4 are seen as the new prediction frontier.
- Progress in prediction of key sources of predictability

Bridging the gap between Climate and weather prediction

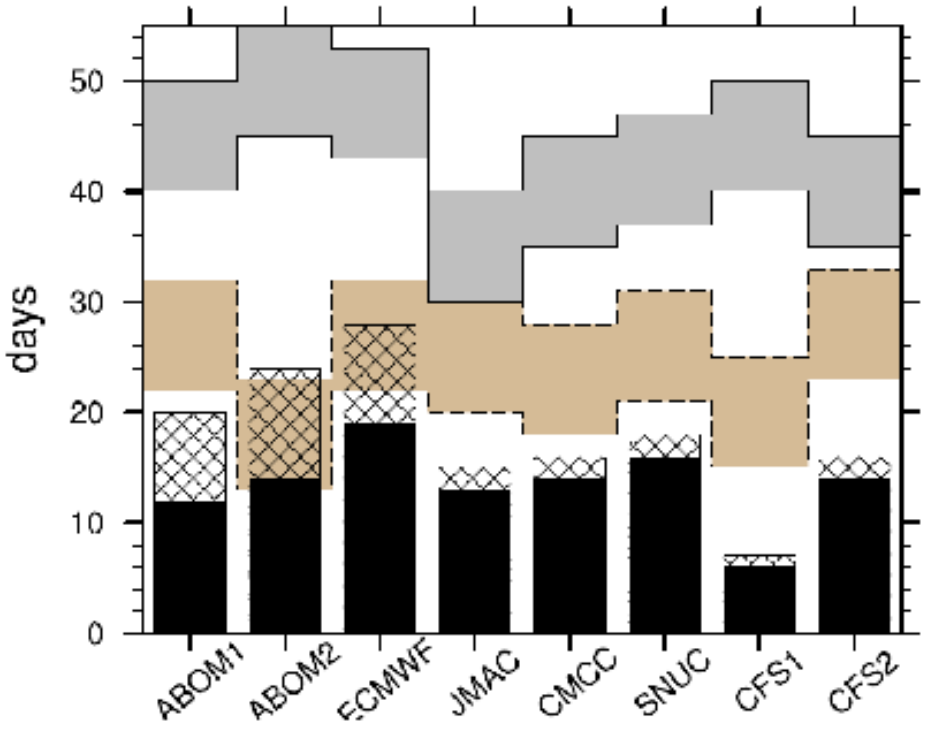
A particularly difficult time range: Is it an atmospheric initial condition problem as medium-range forecasting or is it a boundary condition problem as seasonal forecasting? Is it a predictability desert?

Some sources of predictability – Windows of opportunity :

- Sea surface temperatures
- Land surface conditions: snow, soil moisture
- The Madden Julian Oscillation
- Stratospheric variability
- Atmospheric dynamical processes
  (Rossby wave propagations, weather regimes…)
- Sea ice cover

1st Challenge: to predict the predictors

Capability of MJO forecast



Single member prediction skill ~ 2 weeks

Ensemble mean prediction skill ~ 2-4 weeks

Single member predictability ~ 3-5 weeks

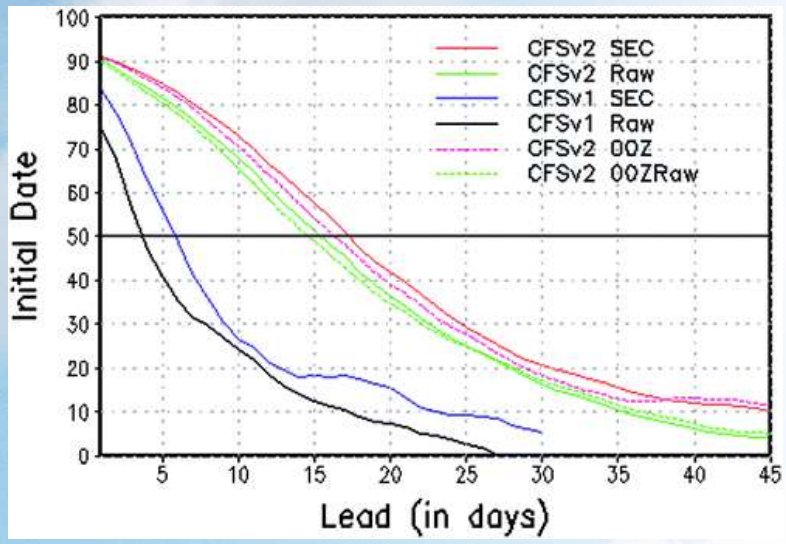
Ensemble mean predictability ~ 5-7 weeks

Neena et al. (2014)

* ISVHE (Intraseasonal Variability Hindcast Experiment)

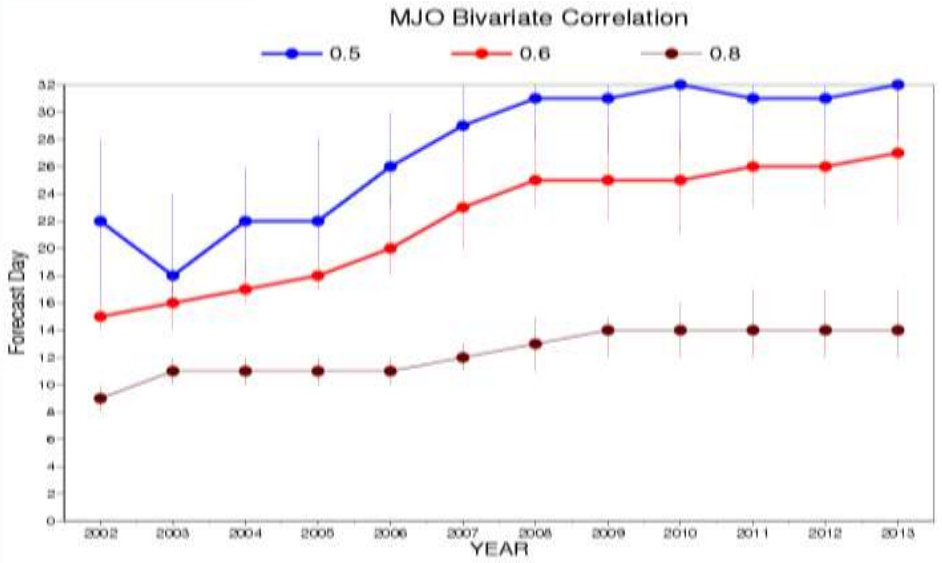
MJO Forecasts have improved

NCEP



Zhang and Van den Dool 2012

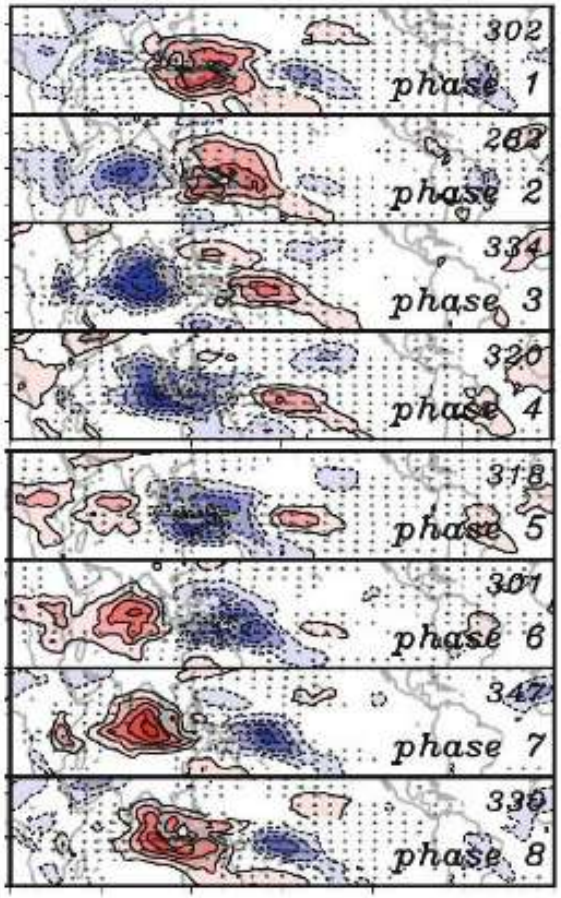
ECMWF



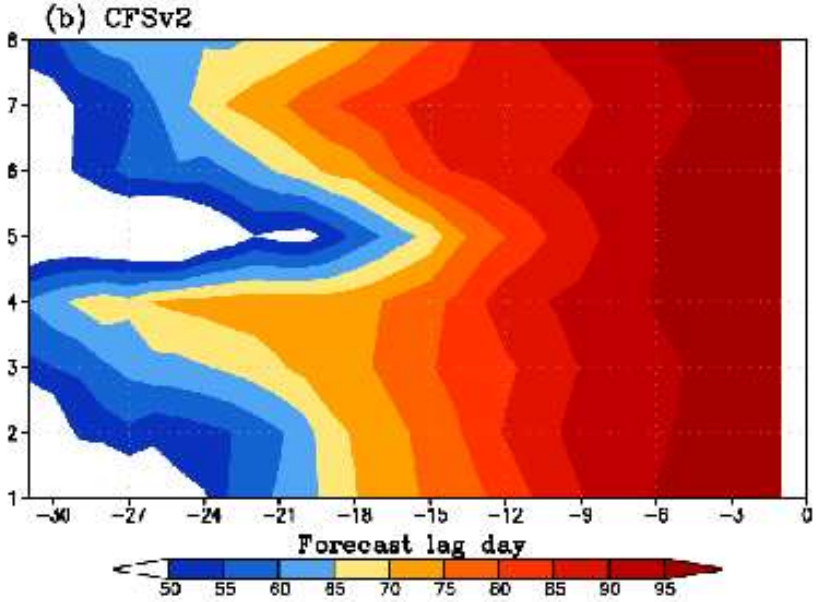
Vitart, 2014

MJO Maritime Continent Prediction barrier

MJO composite



MJO Prediction skill by target MJO phase



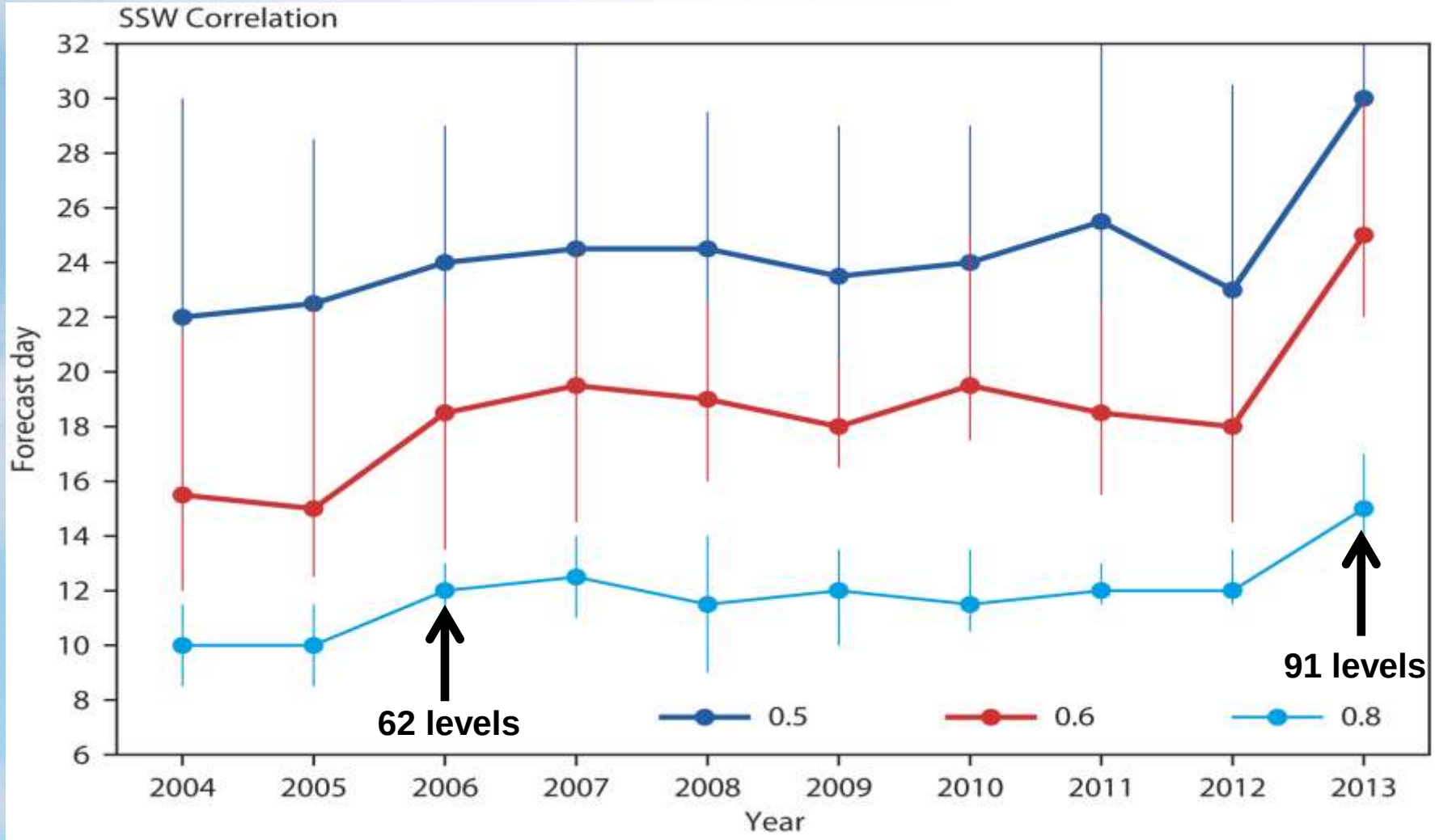
- CFSv2 shows sharp decrease in skill at phase 1 and 5

→ deficiency in predicting the enhanced (or suppressed) convective signal associated with the MJO over the Maritime Continent.

Kim et al. (2014)

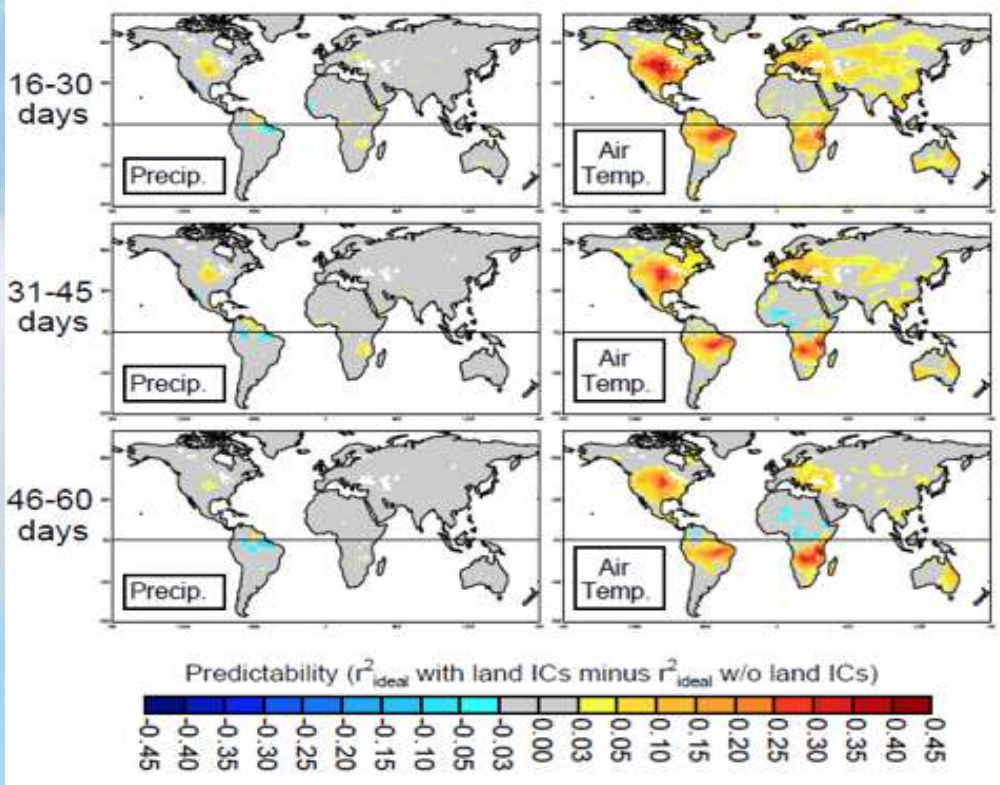
Year Of Maritime Continent - 2017

Sudden Stratospheric Warming



SSW index: Difference of temperature at 50hPa between 90N and 60N averaged over all the longitudes

Impact of soil moisture

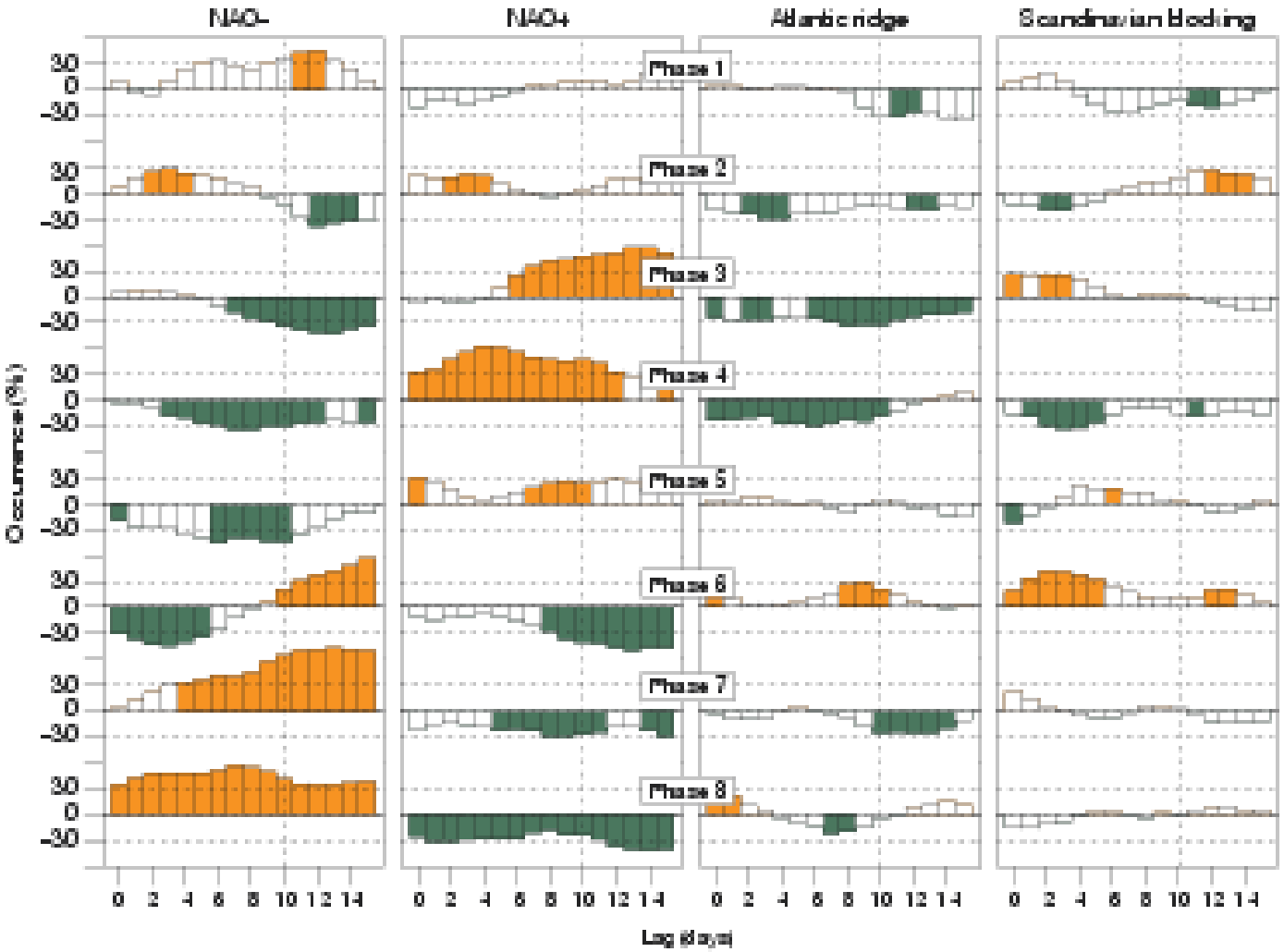


Koster et al, GRL 2011

Soil moisture/temperature initialization is a challenge. Snow depth, sea-ice thickness are also difficult to initialize due to lack of observations.

2nd Challenge: to predict the impact of the predictors

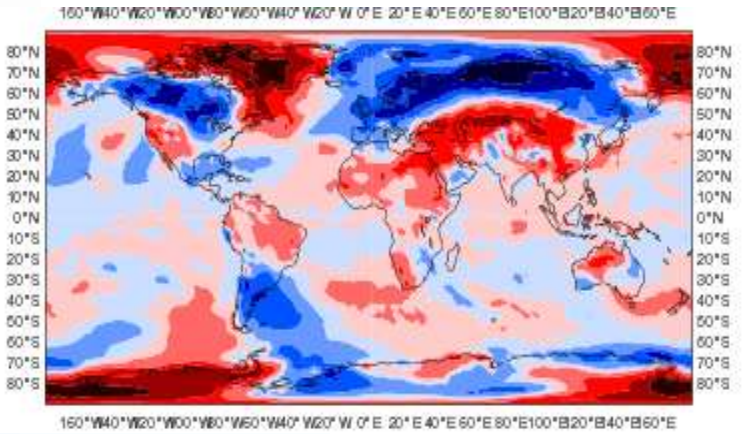
Impact of MJO on Euro-Atlantic weather regimes

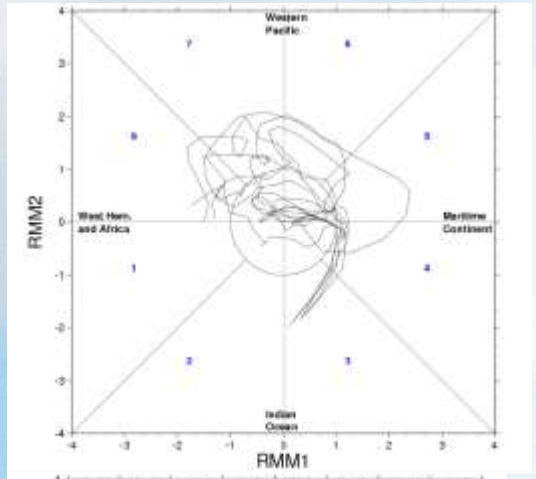


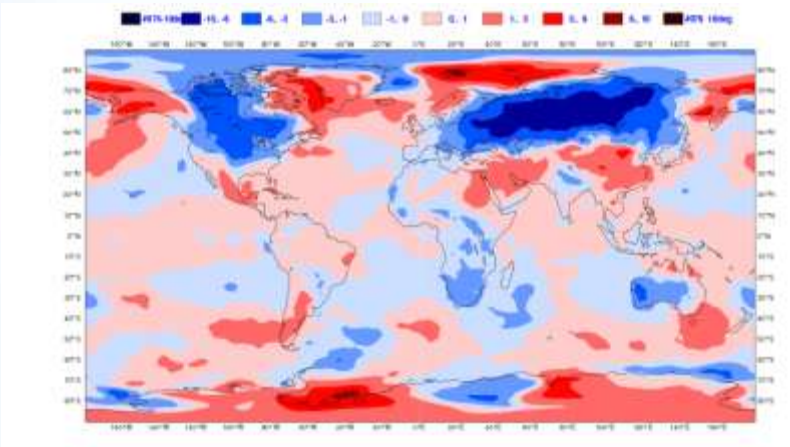
Cassou (2008)

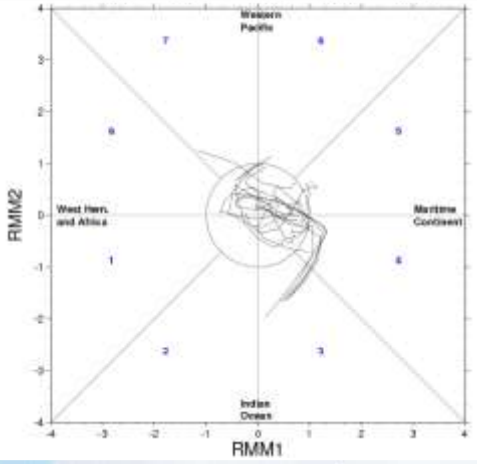
Cold March 2013 – 14 Feb 2013 -Day 26-32

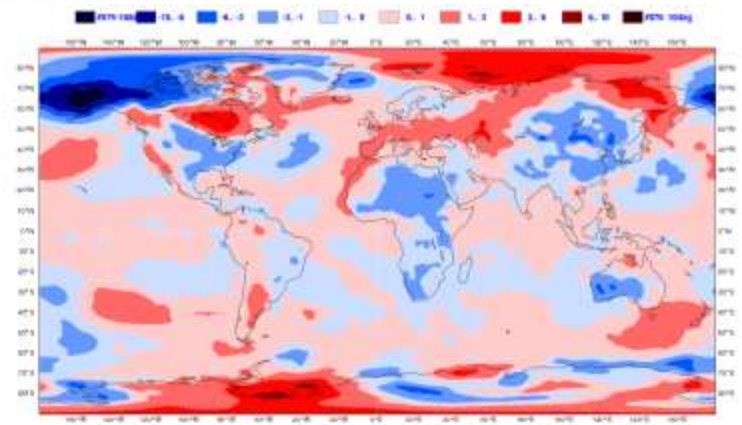
CFS.V2





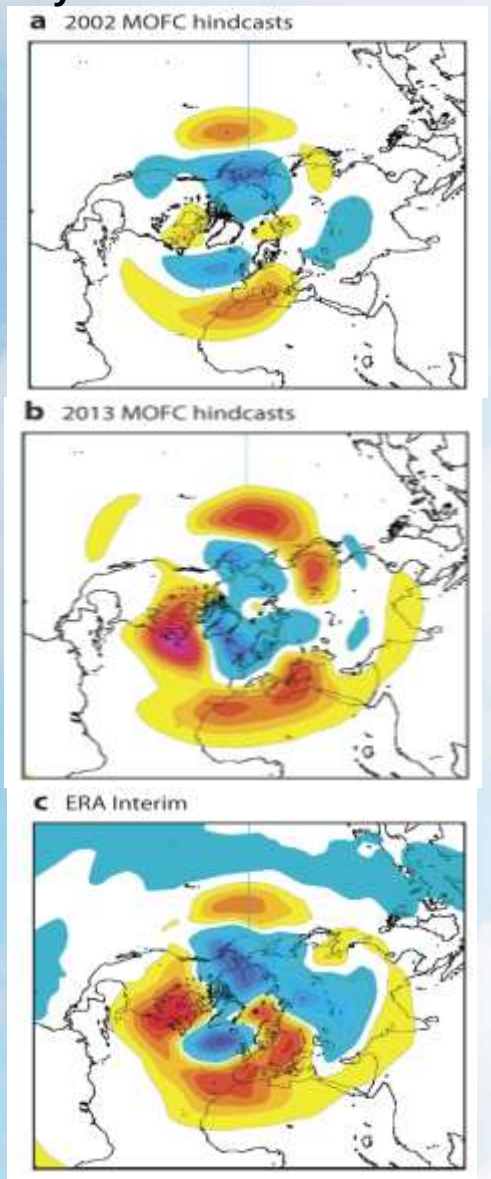






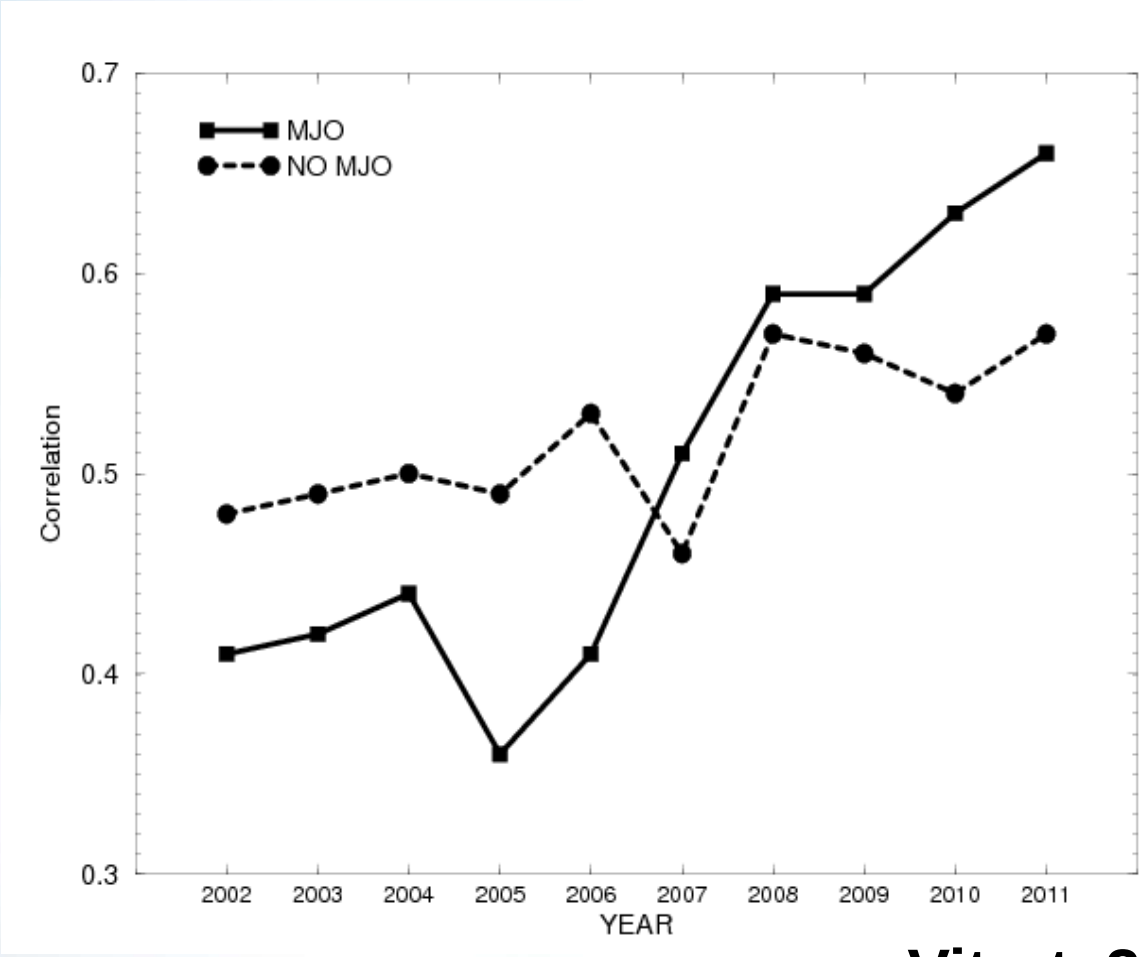
MJO teleconnections

Z500 anomalies
10 days after an MJO in Phase 3



Evolution of NAO skill scores-Day 19-25

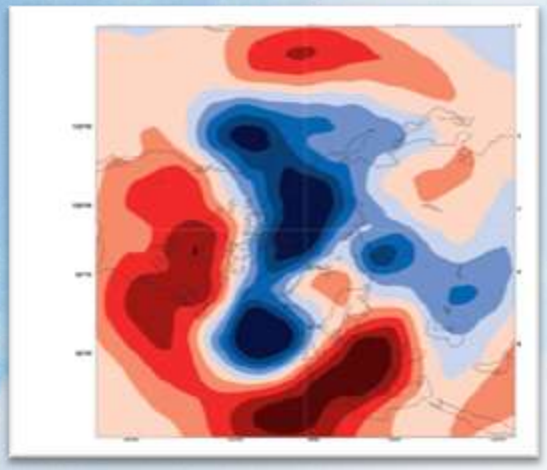
NAO Index: projection of Z500 on pre-computed EOF



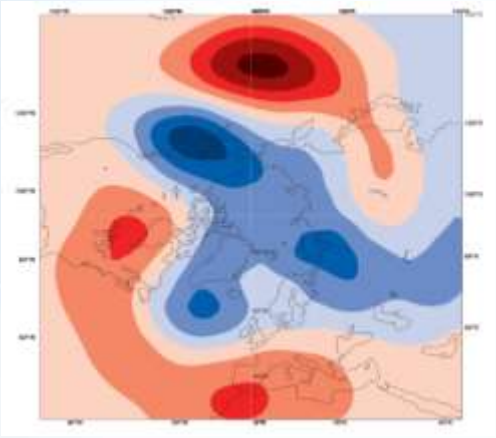
Vitart, 2014

MJO Teleconnections (S2S re-forecasts)

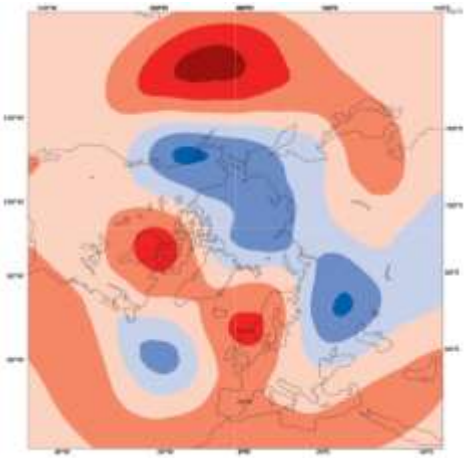
Analysis



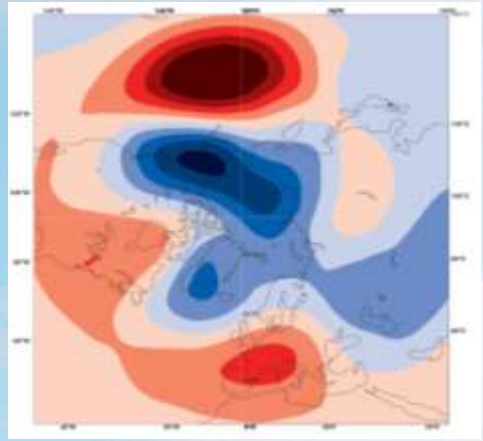
ECMWF



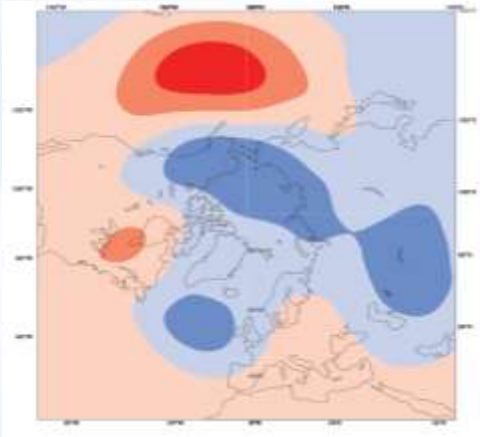
JMA



NCEP



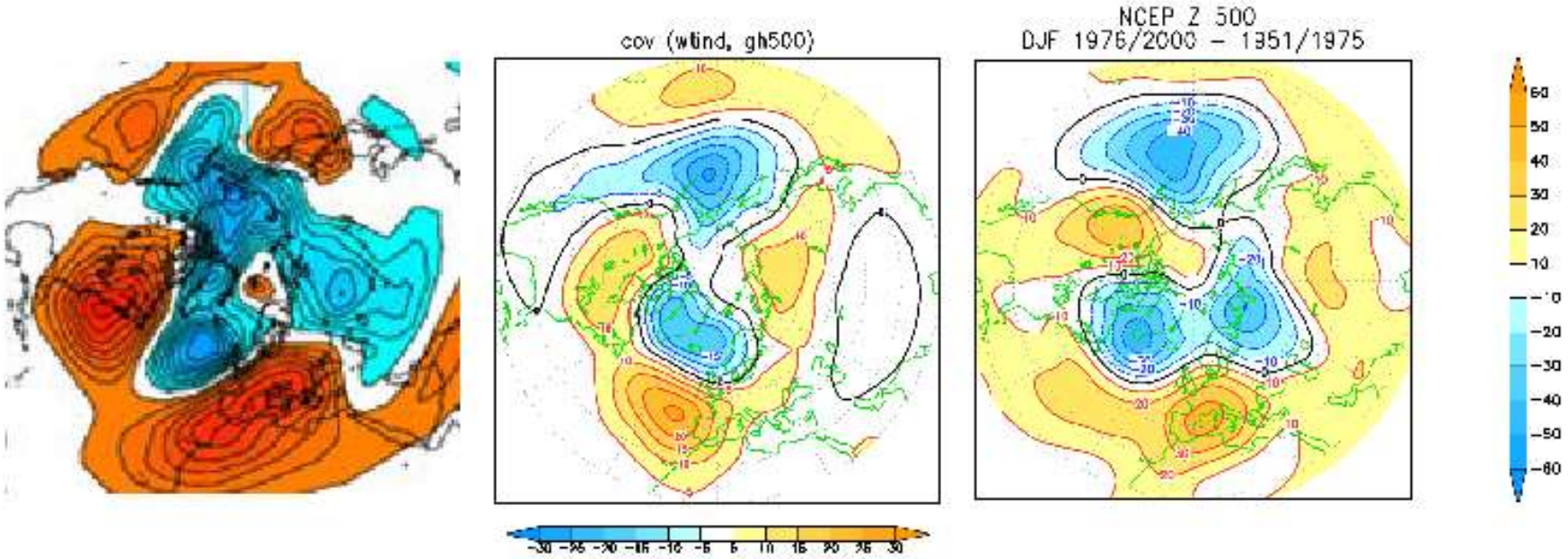
CAWCR



Z500 anomalies 10 days after an MJO in Phase 3

Subseasonal-to-Seasonal S2S Prediction Project

A planetary-wave signal common to different time scales?



Z 500hPa anomaly

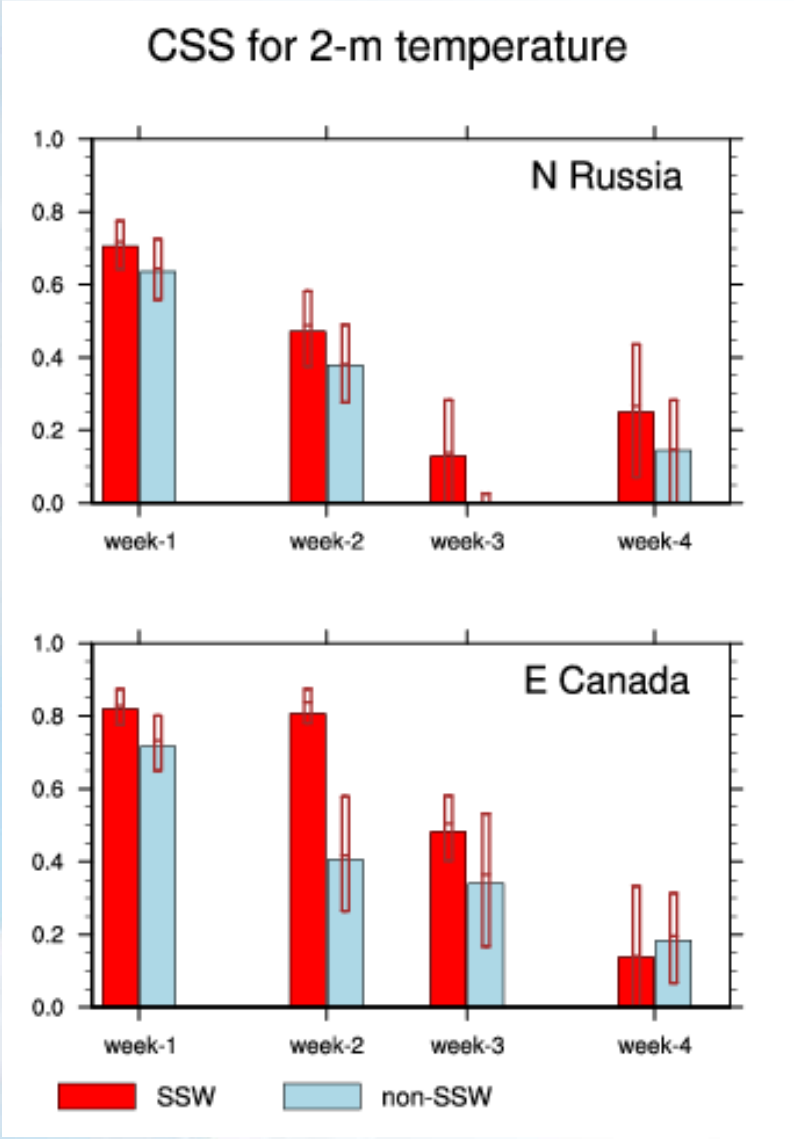
MJO phase3 + 10d

DJF W. Indian Oc. Rain

20th C. decadal variability

Molteni et al, 2014

Impact of SSWs on forecast skill scores

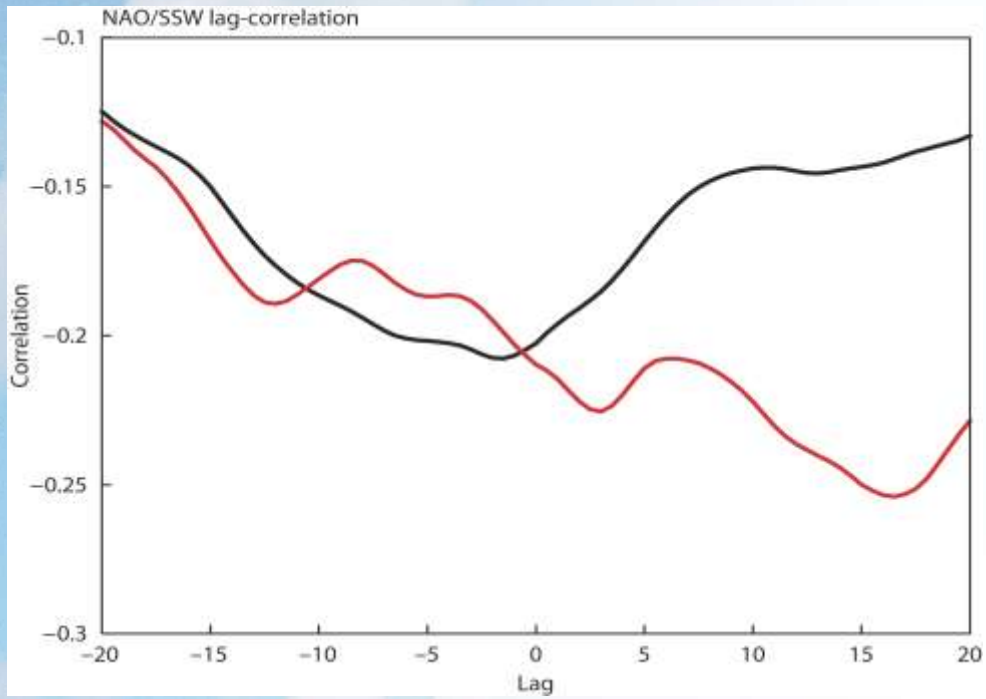


From Om Tripathi, 2015

Sudden Stratospheric Warming

SSW: Downward propagation too weak in the model?

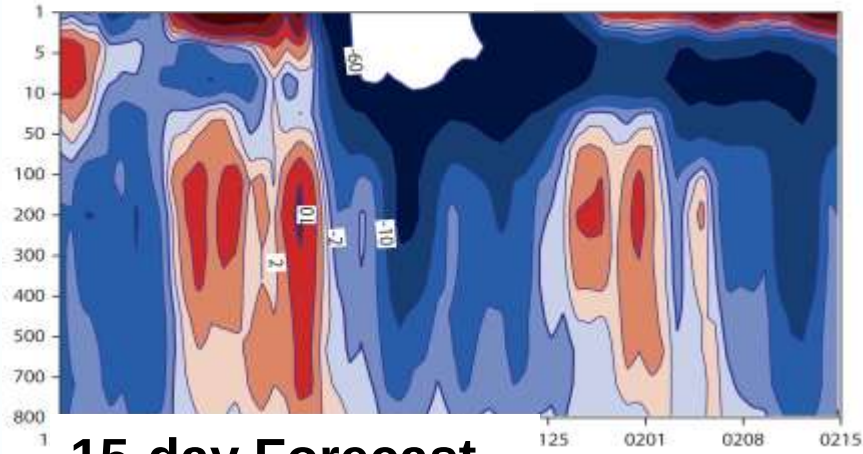
NAO/SSW lag correlation



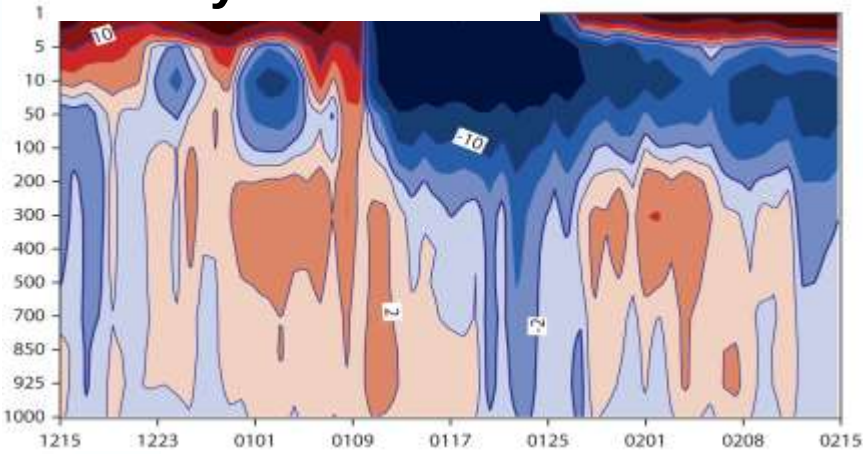
Forecast ERA-I

Zonal Wind Anomaly at 60N over Europe (15 Dec 2012-15 Feb 2013)

Analysis



15-day Forecast



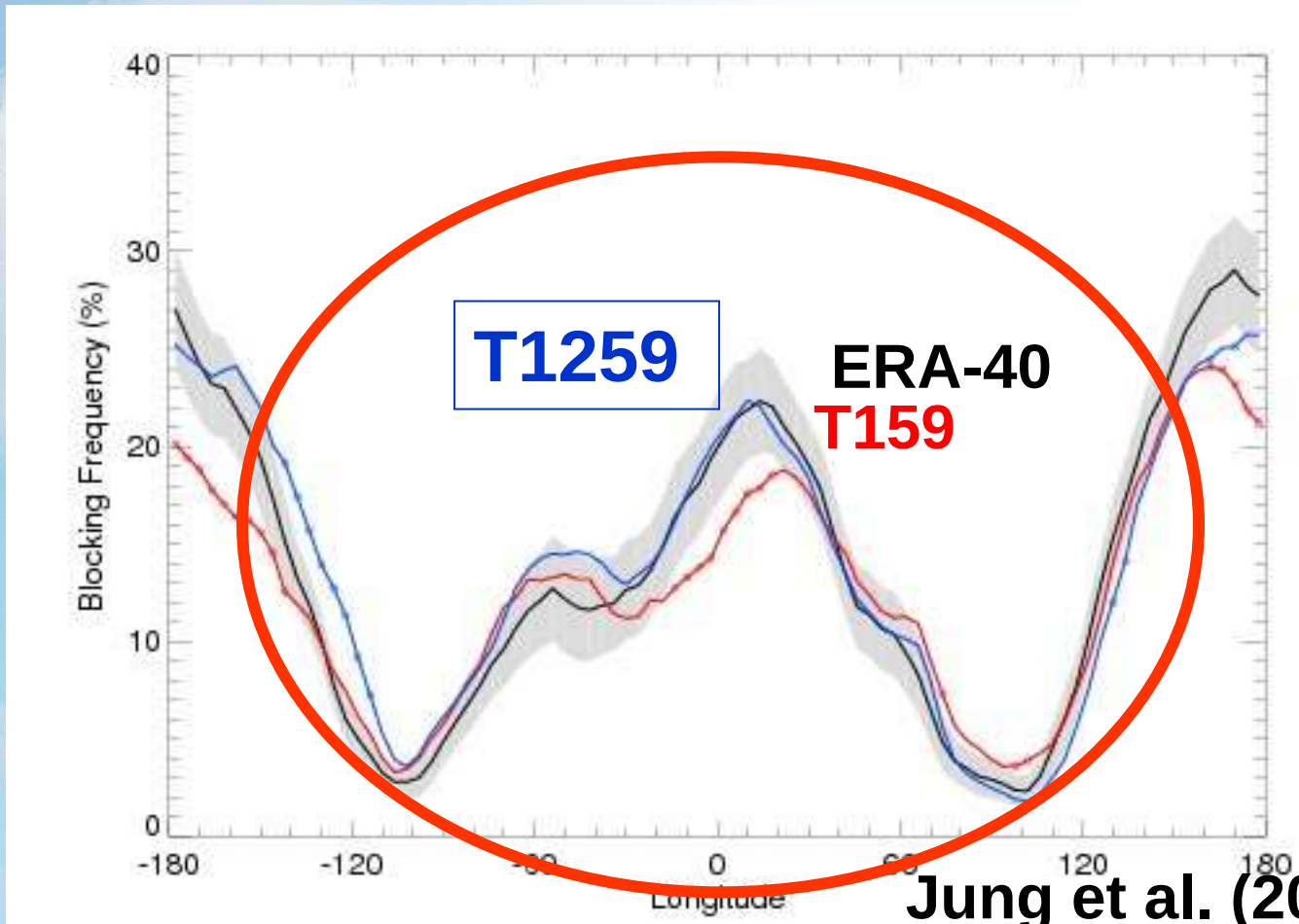
Design of forecasting systems

Modelling issues

- Impact of resolution (Ocean, atmosphere)
- Role of ocean-atmosphere coupling
- Systematic errors
- Initialisation strategies for subseasonal prediction – (Coupled data assimilation)
- Ensemble generation (Burst of lag ensemble? Coupled ocean-atmosphere perturbations?)
- Spread/skill relationship
- Verification (flow dependent verification, verification of precipitation…)
- Benefit of Multi-model forecasting
- Re-forecast size and length

Impact of resolution

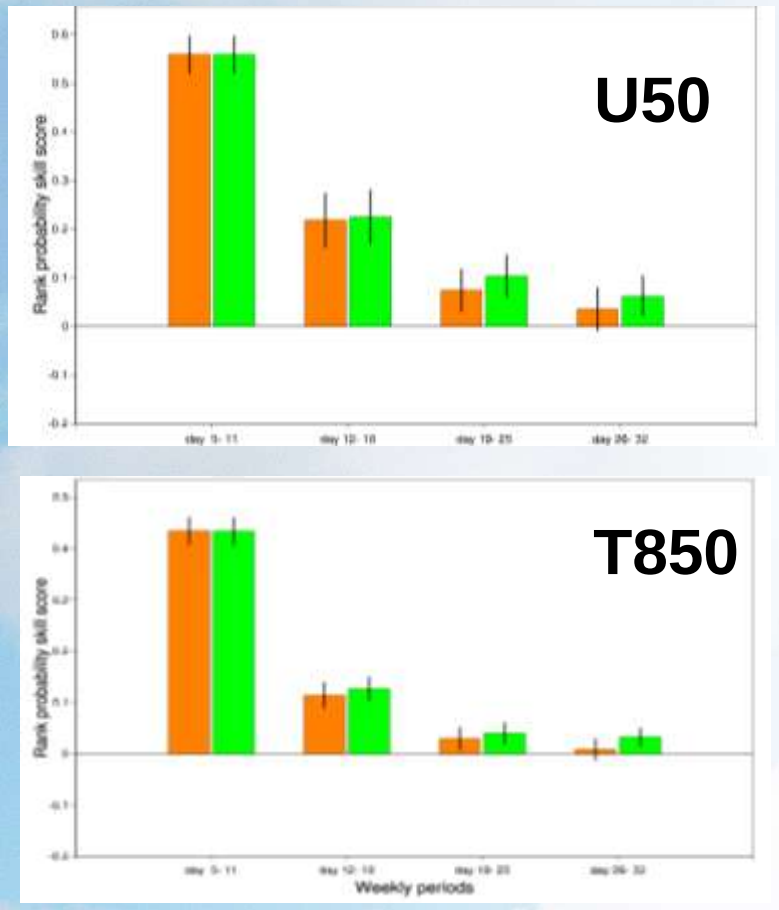
Blocking Index. 13 month integrations of ECMWF model (at T159 and T1259). DJFM 1960-2003- Project ATHENA



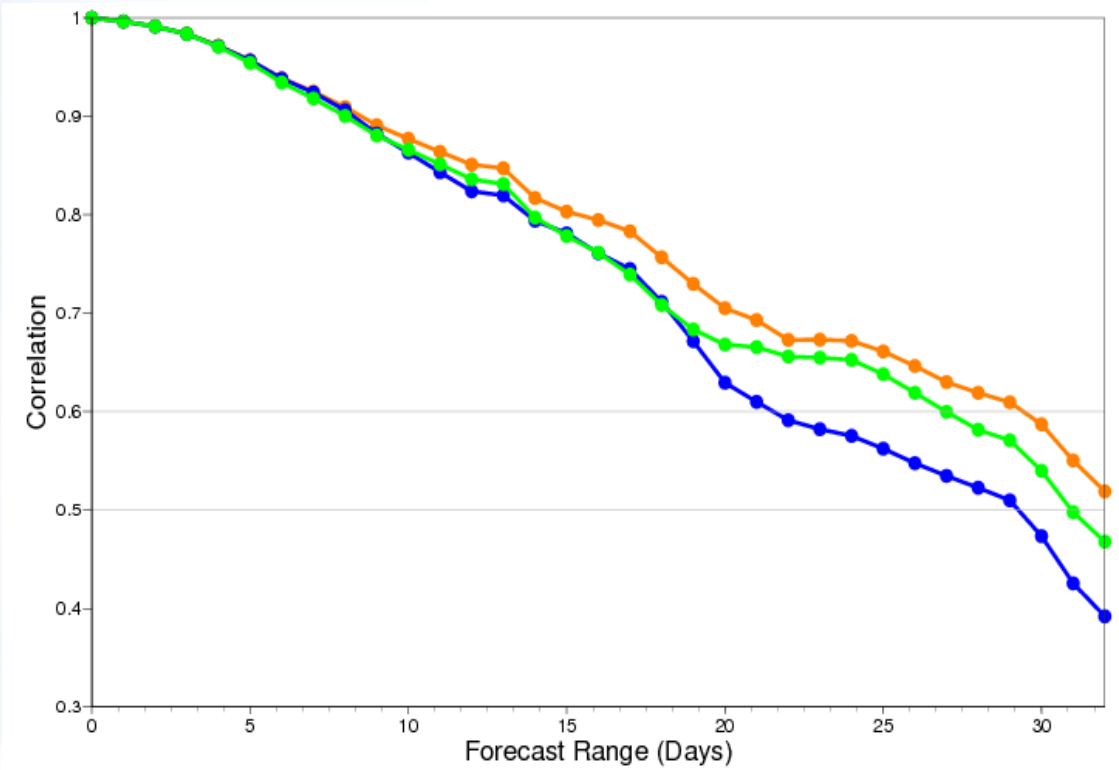
Jung et al. (2012), J. Climate

Ocean-Atmosphere coupling

RPSS over NH



MJO Bivariate Correlation



80 case, starting on 1st Feb/May/Aug/Nov 1989-2008

Re-forecast strategy

Re-forecasts are used for model calibration and also for skill assessment.

- A large reforecast database is needed for calibration to distinguish between random error and systematic errors and also to estimate flow dependent errors.

- A large reforecast database is also needed for verification and for flow dependant skill assessment, like assessing the concurrent impact of ENSO and specific phases of the MJO on the forecast skill scores. Signal to noise ration is also improved in long reforecast datasets (Shi et al, 2014)

- Large ensemble size is also important for skill assessment , since some probabilistic skill scores are impacted by the ensemble size.

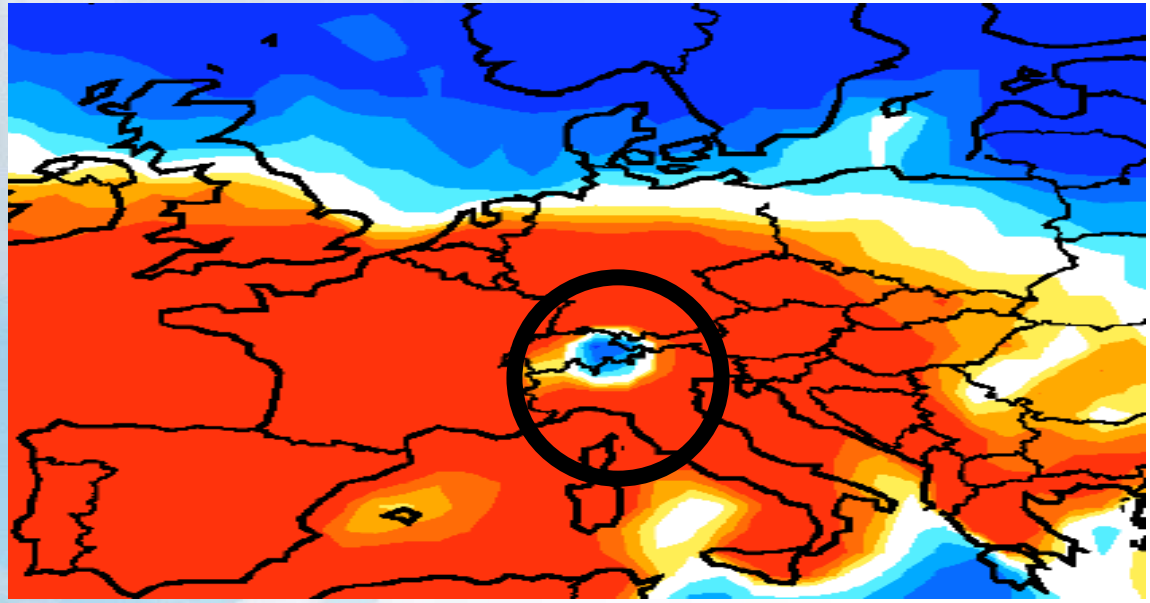
However

- Large re-forecast datasets with large ensemble size are often not affordable. Not clear what is more important: ensemble size, number of years?

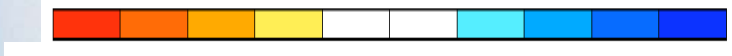
- Long re-forecasts suffer from inconsistent quality in the initial conditions (pre-satellite period).

Problem with re-forecast initial conditions

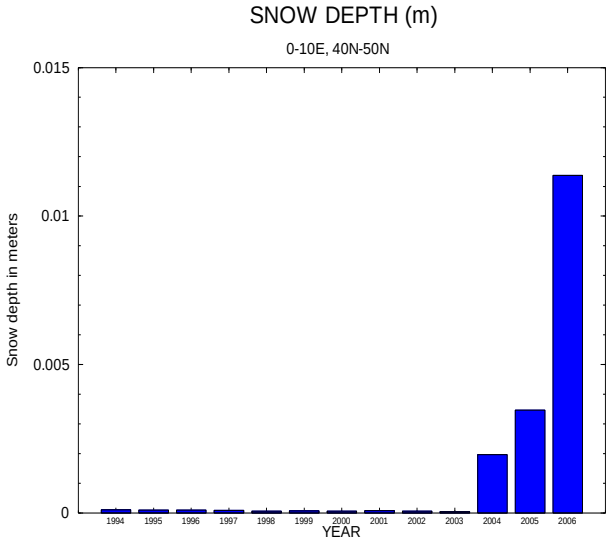
Forecast of week 1
Start: 11-05-2006



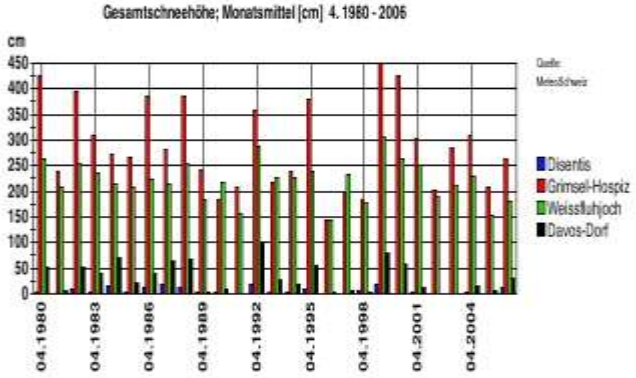
Probability of T_{2m} to be in lowest tercile



Snow ANALYSIS 11 MAY



Observations



The sub-seasonal to seasonal prediction project (S2S)

- "To improve forecast skill and understanding on the sub-seasonal to seasonal timescale with special emphasis on high-impact weather events"
- "To promote the initiative's uptake by operational centres and exploitation by the applications community"
- "To capitalize on the expertise of the weather and climate research communities to address issues of importance to the Global Framework for Climate Services"

Sub-seasonal to Seasonal (S2S) Prediction Project

Sub-Projects

- Interactions and teleconnections between midlatitudes and tropics
- Madden-Julian Oscillation
- Monsoons
- Africa
- Extremes
- Verification

Research Issues	Modelling Issues	Needs & Applications
• Predictability • Teleconnection • O-A Coupling • Scale interactions • Physical processes	• Initialisation • Ensemble generation • Resolution • O-A Coupling • Systematic errors • Multi-model combination	Liaison with SERA (Working Group on Societal and Economic Research Applications)

S2S Database

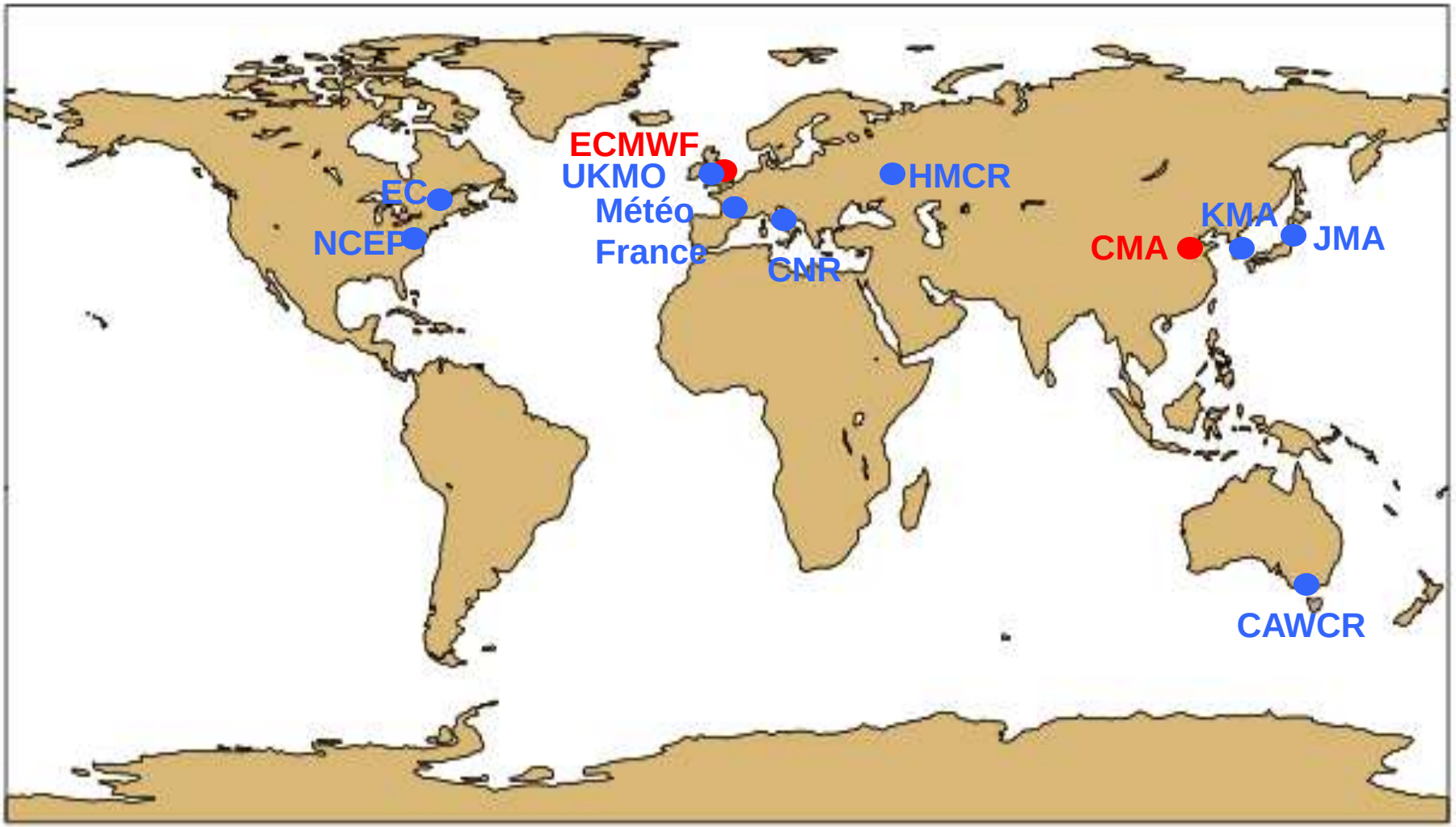
Database Description

- Daily real-time forecasts + re-forecasts
- 3 weeks behind real-time
- Common grid (1.5x1.5 degree)
- Variables archived: about 80 variables including ocean variables, stratospheric levels and soil moisture/temperature
- Archived in GRIB2 – NETCDF conversion available
- Database to open in 2015, initially with 3 models (ECMWF, NCEP and JMA)

S2S Database

11 data providers and 2 archiving centres

- Data provider
- Archiving centre



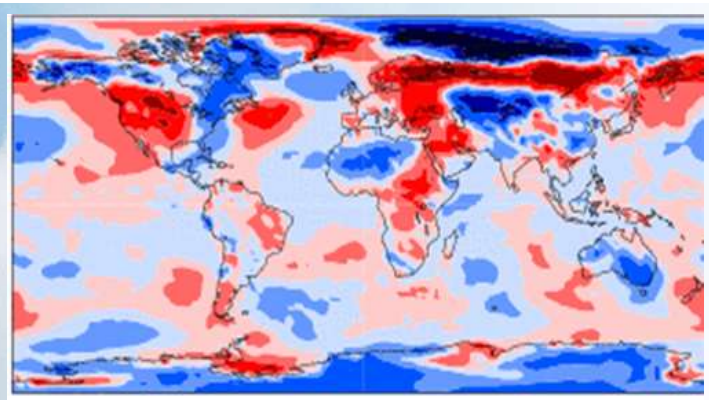
S2S partners

	Time-range	Resol.	Ens. Size	Freq.	Hcsts	Hcst length	Hcst Freq	Hcst Size
ECMWF	D 0-32	T639/319L91	51	2/week	On the fly	Past 20y	weekly	5
UKMO	D 0-60	N216L85	4	daily	On the fly	1996-2009	4/month	3
NCEP	D 0-45	N126L64	4	4/daily	Fix	1999-2010	4/daily	1
EC	D 0-35	0.6x0.6L40	21	weekly	On the fly	Past 15y	weekly	4
CAWCR	D 0-60	T47L17	33	2/week	Fix	1981-2013	6/month	33
JMA	D 0-34	T159L60	25	2/week	Fix	1979-2009	3/month	5
KMA	D 0-60	N216L85	4	daily	On the fly	1996-2009	4/month	3
CMA	D 0-45	T106L40	4	daily	Fix	1992-now	daily	4
Met.Fr	D 0-60	T127L31	51	monthly	Fix	1981-2005	monthly	11
CNR	D 0-32	0.75x0.56 L54	40	weekly	Fix	1981-2010	6/month	1
HMCR	D 0-63	1.1x1.4 L28	20	weekly	Fix	1981-2010	weekly	10

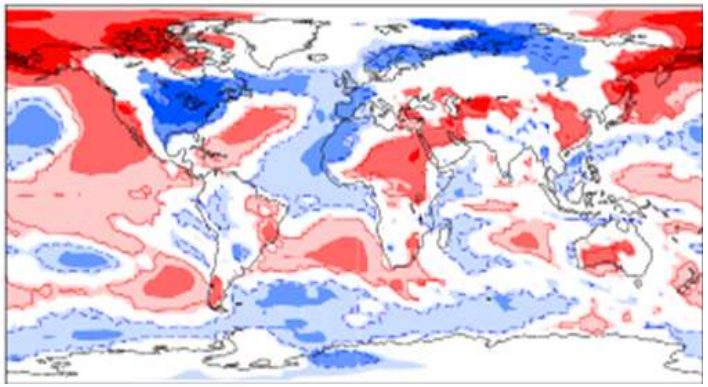
S2S Database products

Day 12-18 2-m temp anomalies - Forecasts starting on 15/01

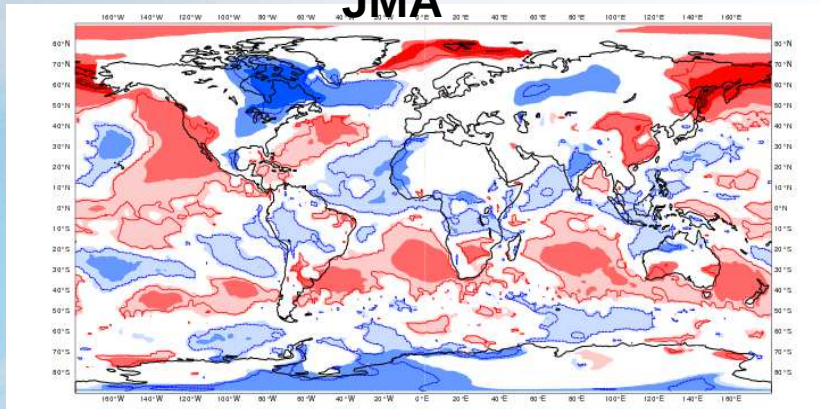
Verification



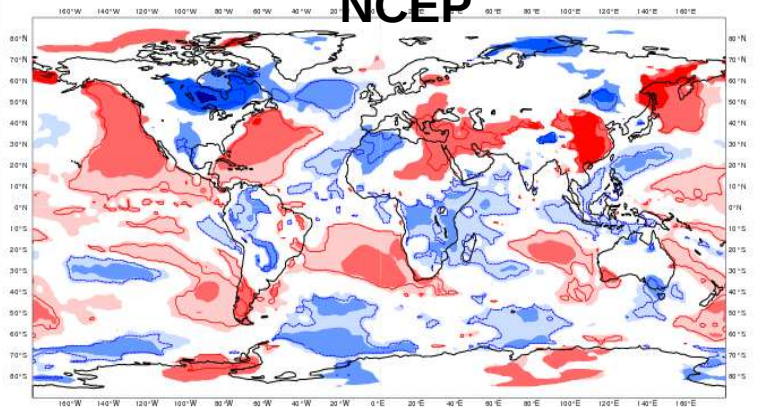
ECMWF



JMA

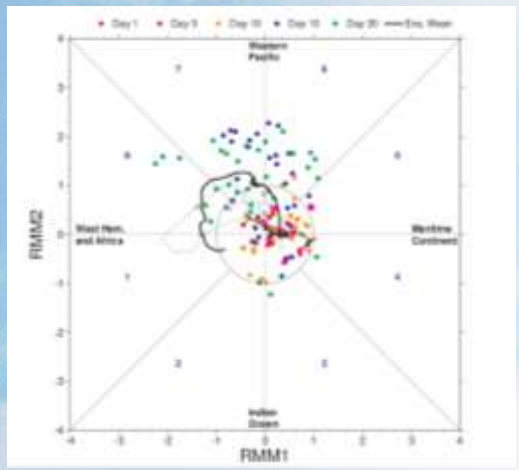


NCEP

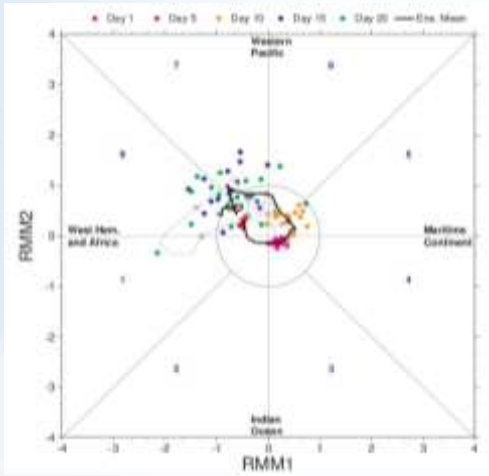


MJO forecast – 26/02/2015

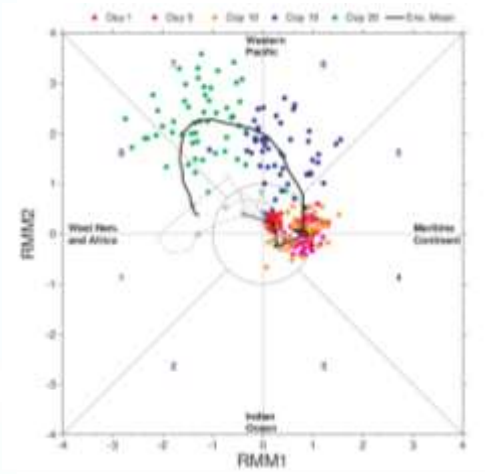
CAWCR



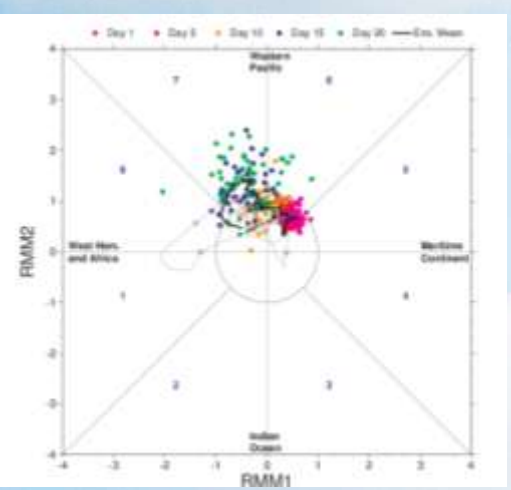
NCEP



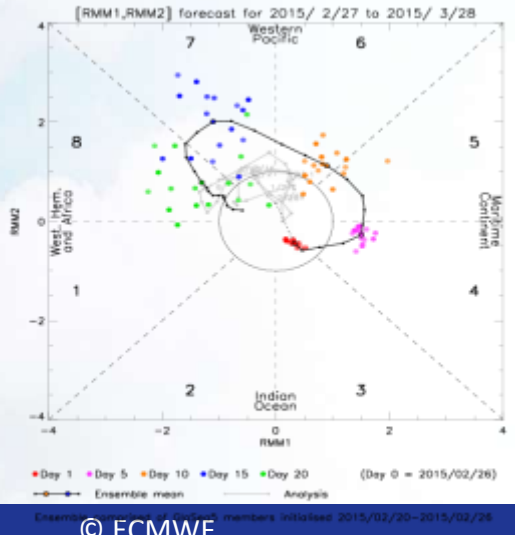
ECMWF



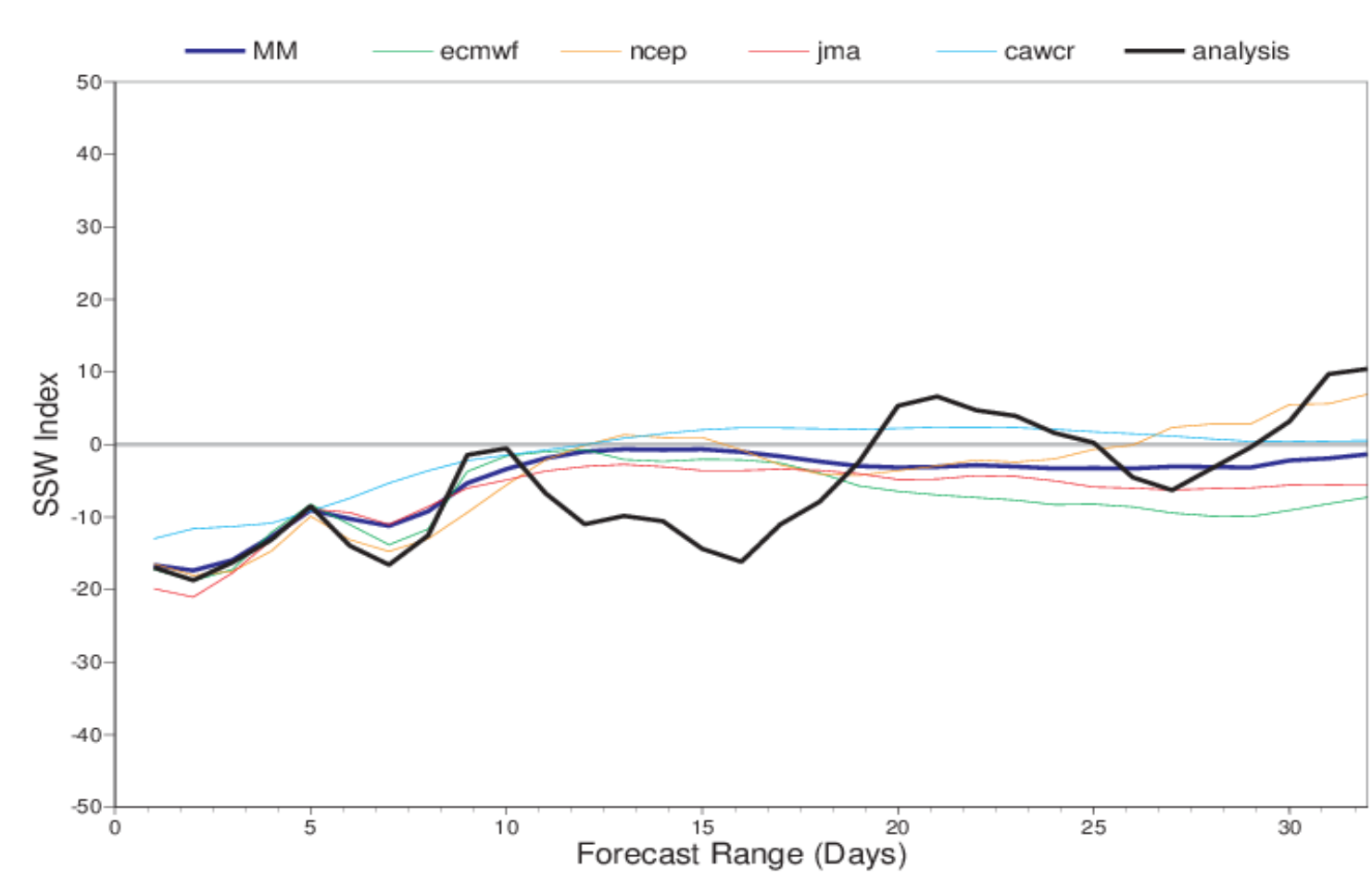
JMA



UKMO



SSWs - 1st January 2015



Conclusion

- Increased interest for this time range – New frontier for prediction
- Progress in the prediction of main sources of predictability over the past decade
- Next challenge is the accurate simulation of their impact and better understand their interaction (e.g. MJO-ENSO)
- Real-time and re-forecast configurations are very different in operational centres. It is not clear yet what is the best strategy.
- WWRP/WRCP S2S project to address some of these challenges